BME EDUCATION - THE PROJECT ORGANIZED AND PROBLEM BASED LEARNING MODEL IS THE CHOICE

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Abstract: A full M.Sc- curriculum in Biomedical Engineering and informatics was established at Aalborg University in 2000. The curriculum reflects the multidisciplinary composition of Biomedical Engineering and consists of engineering, informatics, medical and natural sciences as well as elements from the social sciences.
The education follows the AAU study paradigm with problem-based learning (PBL) and project-organized studies. The first students graduated as Ms.Sc in June 2005. We have now reached an annual uptake of app. 50 students of which 40% are female students. The PBL study paradigm secures high throughput of highly skilled candidates ready for problem solving in industry and health sector bridging between the traditional engineering disciplines and medicine.

Keywords: Biomedical engineering and informatics full master program, problem based learning, project organized.

Introduction

At Aalborg University (AAU) a specialization in Biomedical Engineering and Medical Informatics as in the final stage of the 5-years master curriculum in electronics engineering, has existed since the late 1970's. Since then, a strong development of biomedical research at the university has been the main catalyst for a further expansion of BME curricula. First in a 2-years English-taught master curriculum in BME since 1978, an International Doctoral School (PhD) of Biomedical Science and Engineering, Diploma and Masters in Health Informatics (Open University - Life-long learning), and now latest in 2000 a full five-year MSc-curriculum in Biomedical Engineering and Information Technology.

In a historical perspective BME has emerged from several different parent-fields: Electrical engineering, chemical engineering, mechanical engineering, physics, and other areas all have developed their applications in medicine and biology. Consequently, in most of the places in the world where BME is a graduate program it is typically embedded in one of these fields.

This strategy raises problems. In order to deliver a Biomedical Engineer, it is not optimal first to provide e.g. electrical engineering for three and a half years and then building BME on top of that. Biomedical engineering deserves a better focus from the start of the education. From a student's point of view the road to BME through electrical engineering is a long one. Many students simply don't even start on that road, or have no idea that it exists. This means that an enormous potential is lost.

As a consequence Biomedical Engineering is establishing itself as an independent discipline. There are now well over 20 universities with undergraduate Biomedical Engineering programs in the USA. In Europe besides Aalborg, full programmes have emerged in The Netherlands and lately also in Copenhagen.

As a reflection on the above mentioned and the facts that Denmark sees an increasing growth of production and export of biomedical equipment and a growing investment in advanced technology in the health sector, Aalborg University developed a 5-year MSc. Biomedical engineering and informatics curriculum (BMEI) to full-fill the demands of highly qualified BME-professionals in the future. The first 18 candidates graduated in summer 2005.

The Aalborg Model – To be taught or to learn

The BMEI curriculum follows the AAU study paradigm with problem-oriented learning and project-organised studies with the student groups as the fundamental structural and pedagogical entity.

This study form has proven to secure a more efficient throughput in terms of study-time and percentage of students finalizing their study compared to the classical study forms. Recent figures shows that while app. 9% of the Danish MSc. students using classical university educational paradigms complete their degree in specified time, i.e. 5 years, then 68% of the MSc. students from AAU do this. If the observation period is extended to include nominal study-time plus 1 year, then 44% of the enrolled candidates from other Danish universities get their degree while 85% of MSc. students from AAU do this.

The back-spine of the PBL study-form, see Fig 1, is the project where the students work with real-world problems, typically from the clinical scene, which are analysed, solved fully or partially, and finally

ISSN: 1727-1983

documented, presented and defended at the examination [1], [2], [5], [6], [7].

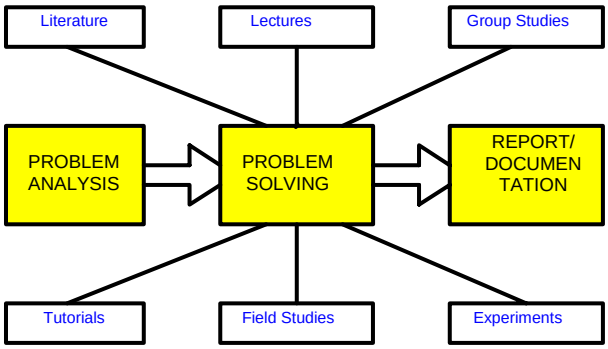

Figure 1: Principles of problem-based and project organised learning. The results from the project work is typically a prototype device/system demonstrated at the examination and documented in a report (100-150 p).

Each semester, lasting 5 month, consists of 30 ECTS units divided evenly between course work and project work. The workload of the course work and project work changes over the semester as illustrated on Fig.2.

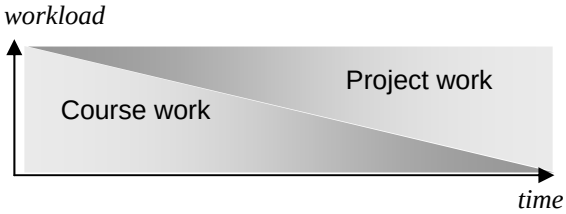

Figure 2: Composition of workload over time in the using PBL with one big project per semester. Note that half of the time is devoted to the project.

Five to seven students work together on a project solving a problem either from a hospital, a company or a research group at the university. The group has a supervisor, a professor from faculty, acting as a consultant - not a problem solver! The groups are allocated a room (app. 18m^2) at campus, this serve as their personal workspace equipped with computers with access to internet and necessary programs for their study, see figure 4. The students typically meet in their group room on a daily basis e.g. from 8am to 4 pm. So from day one in their study time the students more or less adapt to the working conditions most of them will meet as candidates. The group will have their internal meetings and meetings with their supervisor in the group room. Course examinations throughout the education are on individual terms. The projects are presented and examined on group basis, but the students are given individual examination and marks.

Curriculum composition

The curriculum in BMEI reflects the multidisciplinarity of Biomedical Engineering and contains elements from medical and natural sciences, classical electrical engineering, as well as parts from social sciences. The study is divided into a bachelor part, a clinical part at the hospital, specializations and a final master thesis year, see fig.3.

Bachelor and clinical years

The first three years in the curriculum are comprised of a freshman year, a discipline oriented year and a clinical year. The freshman year provides the students with basic skills in mathematics, biology and computer science (C-programming) as well as with concepts of social science with emphasis on technology and society. Principles of Medical Technology Assessment are introduced and applied in the projects. Through the BMEI-projects often made in close collaboration with the hospital, the students are introduced to the problem-oriented and project-organized paradigm as well as to the health sector. The projects are supported with courses in BME, biochemistry and modeling (Matlab based). Project examples are: Influence on false alarms on patients and personnel in the ICU, Home care technologies and Work related EMG Measurements. Centrally for the projects is a certain level of empiric work at the hospital or in the laboratory. The groups are allocated two supervisors during the freshman year. One professor with technical BME background, the main supervisor, and one professor with background in social sciences are allocated [3], [4].

Third semester introduces anatomy, with theory and animal dissection exercises using rabbits at the anatomical department at Aalborg Hospital. Also medical instrumentation is introduced including safety aspects in the laboratory and measurement techniques. Examples of typical third semester projects are: "ECG-pulse measurement", "Computer-mouse control using EOG", "Body impedance measurements device" and "Stimulator for functional electrical stimulation". The projects on third semester all include bio-instrumentation, safety aspects and measures one or more biological variable from patients or subjects - often the students them selves. As in all semester projects the students must construct a demonstrator - here a physical device which must be proved to function and documented appropriately.

Fourth semester focuses on physiology, microcomputer system design, programming and signal processing in biomedicine. Project examples are: "EMG-controlled Mouse", "ECG-monitor" and "Digital stethoscope". The 4th semester projects will all use a microcontroller as the core of the problem solution. The students will construct the appropriate interface electronics and program the microcontroller in C. The user interface will typically be made on a PC connected to the microcontroller system. The students will typically program the PC using Labview.

Courses on third and fourth semesters are Mathematics including continuous and discrete calculus, Electric Circuit Theory, Physiology and Anatomy, Bioinstrumentation, Basic Digital Electronics, Electromagnetism, System Architecture

ISSN: 1727-1983

and Integration, Signal Processing, System design and C-programming.

On 3rd and 4th semesters the students have to build and document an operable prototype which they will demonstrate at the examination.

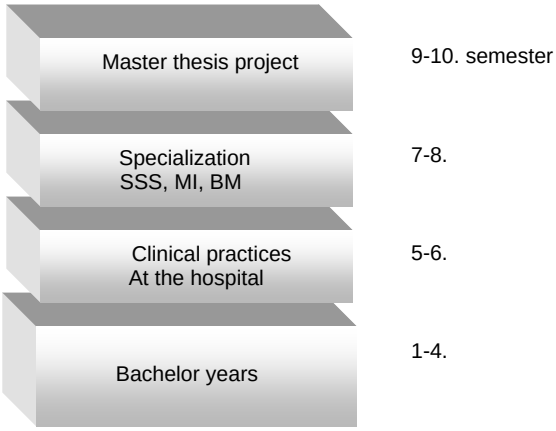

Figure 3: BMEI-MSc-programme composition. MSS: Medical Signals and systems, MI: Medical Informatics, BM: Biomechanics.

Fifth semester focuses on the clinical work at the hospital departments. The projects take place at different hospital departments at Aalborg Hospital and the students have group rooms at the hospital. The students follow the daily routine at the department they are allocated. The projects have out-spring in the clinical problems from the departments and the students have both a clinical and a faculty supervisor. Examples of projects are: Diagnosis of Hydrocephalus, Data Flow in a Hospital Department, Temperature measurement in children.

On the sixth semester the students are still physically located at the hospital. But where the projects on 5th mostly are analytical in nature, the students are supposed to design solutions on the sixth semester. Courses on the clinical year covers: Internal medicine and surgery, theory and clinic, hospital hygiene, organisation and ethics, microbiology, hospital systems, physics and OO-design and programming (UML and Java).

Specializations and MsSc-thesis years

In the last two years the students are specialized but a common course core exists to ensure that all students manage central topics. Three specialisations are offered for the time being: Medical Informatics, Sensors, Signals and Systems and Biomechanics. On the last semesters most of the projects are part of ongoing research projects and provide the students with insight in scientific research planning and execution.

Many of the students choose to spend up to a full semester abroad on another university on the last part of the education. A one-year project with one of the research groups at the university or the hospital makes the final specialisation. The final projects are made by individual students or two students together. Courses in the specialization years cover the different specializations and span from neurophysiology over stochastic mathematics and biostatistics to medical image analysis and medical information systems. Also topics such as medical standards and regulations, ethics and entrepreneurship are covered.

First experiences

By establishing a full graduate curriculum in BME with intake directly from the high school level we believed, and have proved, that it is possible to attract more students due to larger visibility of the BME-program as opposed to classical graduate programmes where students have to “pass” a traditional engineering study before reaching the BME-specialisation. The student uptake in 2000 were 33 and in 2004 56. A positive bonus is that the percentage of female students is around 40%. A very high percentage compared to the normal level of <5% female students on e.g. the electrical engineering study. What is also very interesting is that it has shown that the curriculum and study form equips the student well for future jobs.

Figure 4: BMEI students at work in their group room. Each student group is allocated a room (app. $3m^2$/student) as workspace throughout the semester. They typically meet their a full working day tie. 8am-4pm.

Several student projects have taken awards; some student projects have been so promising that patents are applied for; some projects are being handed over to private companies. A single project initiated at the first 7th semester in the history of the education has been so succesfull that a patent has been filed and a licence contract with one of the largest companies has just recently been established. Some of the students have established private companies - even before graduation. In a newly established incubator on the Department for Health Science and Technology at AAU six of the first candidates are now pursuing their carrier as innovators [8].

Both hospital and industry are giving very positive testimonials. In a survey covering all universities in DK, the educations at AAU, all based on PBL and

ISSN: 1727-1983

group work, shows to have the highest percentage of candidates finalizing their study, and doing it on normalized time!

The Future

In the near future the BMEI curriculum will be adapted to the Bologna model and some of it will be taught in English, making it possible to exchange students with universities abroad. New specializations and adjustment of the existing will also be implemented. A specialization in tissue engineering with elements of bio- and nanotechnology is under planning [4].

We are quite convinced that the BMEI curriculum implemented at AAU full-fill the requirements from the relevant consumers of the candidates, i.e. the BME-industry, the health sector and the academia with respect to factual knowledge within biomedical engineering, medicine and informatics etc. We are even more convinced that the ability to crack real-life problems, to document the process and solutions, to collaborate with peers and colleagues with different background as taught and **learned** using the Problem Based Learning paradigm will ensure that the candidates will significantly contribute to the companies and departments where they get employment and thereby to the society as so.

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ISSN: 1727-1983